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Duration of operation in association with surgical site infection in Saudi Arabia: A systematic review and meta-analysis

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ABSTRACT

Introduction: Although surgical site infections (SSIs) are preventable complications of surgical procedures, they continue to represent a threat to public health, having a critical effect on patients and healthcare systems.

Methodology: A systematic search was conducted through Google Scholar, PubMed, Scopus, Web of Science, and Cochrane to include the relevant literature in this systematic review and meta-analysis. Review Manager 5.4 to conduct a quantitative data synthesis for the analyses. Random-effects meta-analysis was used to assess the effect of operation duration as a potential risk factor on SSI. **Results:** A total of 7 studies were eligible for this study with 3583 patients included. The estimated pooled SSI prevalence among post-operative patients in Saudi Arabia was [0.09 (95% CI; 0.05, 0.12)] with significant heterogeneity level ($I^2=93\%$; $P<0.001$). The duration of operation of the seven studies was significantly different between those who developed postoperative SSI and the control group [$SMD=0.78$, (95% CI; 0.22, 1.34), $P=0.006$]. **Conclusion:** We reported a relatively high prevalence of postoperative SSI in Saudi Arabia. The least SSI prevalence rate was found among women who underwent cesarean section while the highest prevalence rate was associated with autologous cranioplasty. We also found that prolonged duration of operation was significantly associated with a higher incidence of postoperative SSI.

Keywords: surgical site infection, wound infection, operation duration, Saudi Arabia



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1. INTRODUCTION

Surgical-site infection (SSI) is a worldwide healthcare issue that increases patient mortality, morbidity, and healthcare costs. The Centers for Disease Control and Prevention (CDC) identified SSI as an outgrowth of pathogenic micro-organisms at the wound site inside the skin and subcutaneous fat, musculo-fascial layers, or organs or cavities exposed during surgery (Bagnall *et al.*, 2009). As the skin is regularly colonized by bacterial flora, an SSI cannot be determined only by the microbiological evidence but must be combined with clinical indications such as redness, heat, pain and swelling, dissociation of the suture line, or development of an abscess in the deeper tissues (Di Benedetto *et al.*, 2013). Wound infections usually develop between the fifth and tenth post-operative days causing minor superficial inflammation in most cases. Nevertheless, SSIs can occur months after surgery if a prosthetic has been inserted (Bagnall *et al.*, 2009).

Despite the fact that more than half of SSIs are preventable (Umscheid *et al.*, 2011), SSI is the most common HAIs in developing countries, which affects up to 30% of patients undergoing surgery. Even in high-income economies, it is still the second most common form of HAI, representing more than 20% of HAIs (Zhang and Li, 2020). Based on a five-year assessment of hospitals in the United Kingdom, the Nosocomial Infection National Surveillance Service (NINSS) estimated an incidence of hospital-acquired infection (HAI) due to SSIs as high as 10% in 2002 (Mangram *et al.*, 1999). A prevalence survey conducted in 2006 proposed that around 5% of patients who had performed a surgical procedure acquired an SSI (National Nosocomial Infections Surveillance (NNIS), 2002). These studies may under estimate SSIs' true proportion as certain wound infections could be treated in the community without hospital referral (McDougall *et al.*, 2004).

A meta-analysis was conducted to estimate the prevalence of SSI in the Eastern Mediterranean and presented a high prevalence rate of SSI within this region, nearly twice the global rate. The high SSI prevalence emphasizes the importance of timely diagnosis, prevention, and appropriate post-operative control in this region (Maleknejad *et al.*, 2019). In Saudi Arabia, the rate of SSI was reported to be 6.8% in a teaching hospital, comparable to other literature (Khairy *et al.*, 2011). Duration of operation is frequently reported as an independent and possibly adjustable risk factor for SSI. A systematic review comprehensively demonstrated that prolonged operation duration could increase the chance of acquiring SSI across a wide range of surgical interventions and surgical specialties. Overall, pooled analyses revealed that patients with prolonged operating times had almost twice as likely to acquire SSI.

On average, the mean operative duration was nearly 30 min more in patients with SSIs than those without SSIs. Nonetheless, given the significance of SSIs on patient outcomes and health care economics, including hospital reimbursement implications, hospitals should prioritize efforts to shorten the operative time (Cheng *et al.*, 2017). This systematic review and meta-analysis aim to estimate the pooled prevalence of SSI and assess the duration of operation as a potential risk factor for developing SSI in Saudi Arabia.

2. METHODOLOGY

Study design and duration

This was a systematic review and meta-analysis conducted between 15th April 2021 and 20th May 2021.

Study condition

This study investigates the effect of operation duration on the incidence of SSI in different operative interventions in Saudi Arabia.

Search strategy

An electronic systematic literature search of five major databases; Google Scholar, PubMed, Scopus, Web of Science, and Cochrane was conducted to include the relevant literature. Our search process was limited to the English linguistic and was customized for each database as necessary. The relevant articles were determined through the following keywords that adjusted into Mesh terms in PubMed or subject terms as in Scopus; "surgical site infections", "wound infection", "surgical incision infection", "postoperative", "predictor", "associated risk factors", "operation duration", "procedure time", "time of intervention", and "Saudi Arabia". The relevant keywords were combined using Boolean operators like "OR" or "AND". The reviewers restricted the search results to full texts, free accessible articles, human trials, and the English language.

Selection criteria

Our review included the studies with the following criteria:

All study designs provide SSI prevalence.

Studies provided a number of the duration of SSI operation in hours/ minutes among the patients who developed SSI and the control group.

Studies with control groups.

Exclusion criteria comprised the following:

Studies conducted outside Saudi Arabia.

Studies conducted in a language other than English.

Studies that were not freely accessible.

Data extraction

Rayyan (QCRI) (Ouzzani *et al.*, 2016) was used to determine duplication evaluation features of the results collected from conducting the search strategy. Screening the pooled search results was implemented using a set of inclusion/ exclusion criteria by the researchers to investigate titles and abstracts for convenience. The full-text assessment of the articles that met the inclusion criteria was done by the reviewers. The authors overcame any conflict by debate and discussion. A data extraction sheet was carried out to include the eligible studies. The authors extracted the data related to the study titles, the authors, study year, study design, study population, participant number, age of participants (age range, mean age, or median age), and gender, the prevalence of SSI, and the associated duration of operation in patients with SSI and the control groups were also recorded.

Risk of bias assessment

For evaluation of the quality of the included studies, the Newcastle-Ottawa scale (NOS) (Wells *et al.*, 2000) was utilized for qualitative and quantitative data synthesis. The reviewers investigate and debated any disagreement in the quality assessment. Publication bias was estimated by visual inspection of the funnel plot.

Strategy for data synthesis

Summary tables were presented with the collected details from the eligible studies to formulate a qualitative overview of included research characteristics and outcome data. Following the assessment of the data processing, The scope of the recommended pooled analyses was evaluated. Decisions were made to determine how to better use case and control data after the conclusion of data extraction in this meta-analysis. A qualitative synthesis of the determined data was implemented independently of the viability of the pooled meta-analyses. Studies that met the full-text inclusion criteria but do not include the numerical data of the duration of procedures were not included in our analysis.

The authors used Review Manager 5.4 (The Cochrane Collaboration, 2020) to implement quantitative data synthesis for the analyses on the condition of interest. Random-effects meta-analysis was employed to measure the effect of operation duration as a potential risk factor on the incidence of SSI. Heterogeneity was estimated using an I-square statistic as a portion of the pooled meta-analysis. Publication bias was estimated utilizing funnel-plot and funnel-plot symmetry measures.

3. RESULTS

Search results

A total of 1131 studies were identified from the initial systematic search. Out of these studies, 390 identical annals stood recognized and uninvolved by Rayyan (QCRI). Other 410 studies were removed after the title and abstract screening due to irrelevant findings, wrong study type or design, followed by the full-text assessment and removal of additional 270 studies due to inappropriate analysis or wrong outcome. Eventually, a total of 7 eligible study articles were included in this analysis. The presented selection process and identification are found in Figure (1).

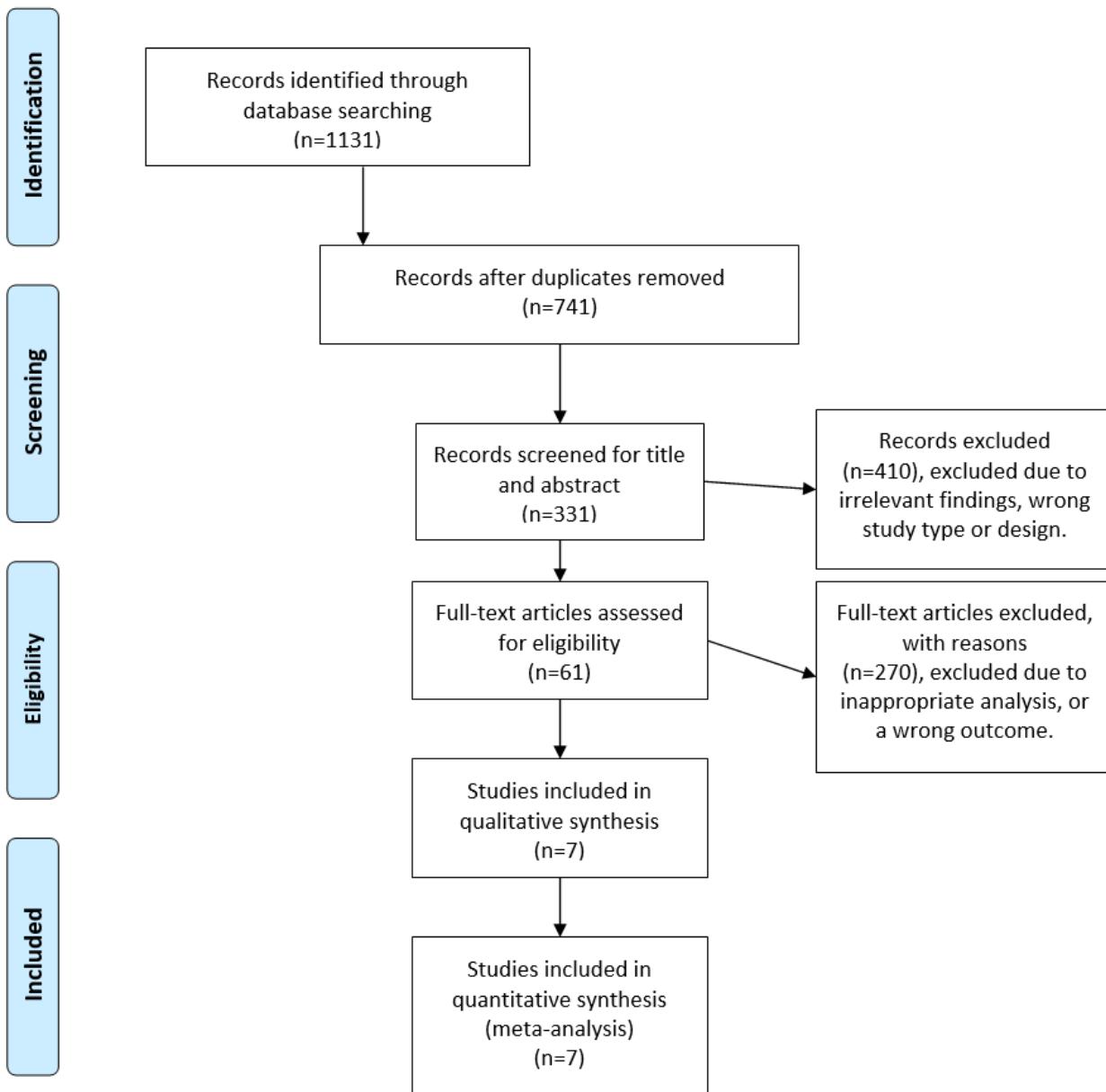


Figure 1 PRISMA Flowchart diagram showing a summary of the selection process.

Characters of the included studies

A total of 7 studies were included for the quantitative data synthesis conducted from 2007 (Al-Khayat *et al.*, 2007) to 2021 (Alghamdi *et al.*, 2021) with a total of 3583 participants. One of these studies was conducted on women who underwent cesarean section (Gadeer *et al.*, 2020), one included the patients with autologous cranioplasty (Alkhaibary *et al.*, 2020), one included patients who underwent pilonidal operations (Al-Khayat *et al.*, 2007), one included patients who underwent spinal surgery (Alghamdi *et al.*, 2021), one included patients who underwent foot and ankle surgery (Al-Kenani *et al.*, 2017), one included patients following abdominal surgery (Alkaaki *et al.*, 2019), and another was conducted on patients who had surgery for any reason and who stayed in the hospital for at least 48 h were enrolled in the study (Alsareii *et al.*, 2017). Out of the included studies, three were conducted in Jeddah (Alghamdi *et al.*, 2021; Alkaaki *et al.*, 2019 & Gadeer *et al.*, 2020), Two were conducted in Riyadh (Al-Kenani *et al.*, 2017 & Alkhaibary *et al.*, 2020), one was conducted in Al-Khobar (Al-Khayat *et al.*, 2007), and one was conducted in Najran (Alsareii *et al.*, 2017). A summary of the typescripts of the involved studies found in Table 1.

Table 1 Summary of the characteristics of the included studies

Study	Study design	Population type	No. of participants	Age range	Age (Median and IQR)	Age (Mean ± SD)	Males (n)	Males (%)	City	SSI Prevalence (n)	SSI Prevalence (%)	Duration of operation in patients with SSI (Mean±SD)	Duration of operation in patients without SSI (Mean±SD)	NO S
(Alghamdi et al., 2021)	Retrospective case-control	Patients underwent spinal surgery	201	^a	56.9	^a	103	51.2	Jeddah	8	3.9	267.8±71.5	169±99.3	6
(Alkaaki et al., 2019)	Prospective cohort study	Patients following abdominal surgery	337	31-61	43.6	^a	144	52.7	Jeddah	55	16.3	196.3±136.3	116±33.5	8
(Al-Kenani et al., 2017)	Retrospective study	Patients who underwent foot and ankle surgery	295	^a	^a	31.77±12.4	154	52.2	Riyadh	10	3.4	136.8±64.6	74±42.4	9
(Alkhaibar et al., 2020)	Retrospective cohort study	Patients with autologous cranioplasty	103	5-67	^a	31.2 ± 14.8	87	84.5	Riyadh	16	15.7	180±60	180±60	6
(Al-Khayat et al., 2007)	Retrospective chart review	Patients who underwent pilonidal operations	100	14-35	^a	21.9	82	89.1	Al-Khobar	12	12	67±31	70.8±29.4	8
(Alsareii et al., 2017)	Cross-sectional observational study	Patients who had surgery for any reason and who stayed in the hospital for at least 48 h were enrolled in the study	2160	16-83	59	^a	1331	61.6	Najran	220	10.2	240±92	130±65	7
(Gadeer et al., 2020)	Retrospective cohort	Women who underwent cesarean section	387	19-51	^a	31.1±5.6	0	0	Jeddah	13	3.4	61.8±21.8	59.4±22.5	8

Analysis of SSI prevalence

This meta-analysis used the random effect model to show the estimated pooled SSI prevalence among post-operative patients in Saudi Arabia [0.09 (95% CI; 0.05, 0.12)] with significant heterogeneity level ($I^2=93\%$; $P<0.001$). The highest SSI prevalence was recorded among patients with autologous cranioplasty [0.16 (95% CI; 0.09, 0.23)], while the least prevalence was found among women who underwent cesarean section [0.03 (95% CI; 0.02, 0.05)] (Figure 2).

Effect of duration of operation on SSI

The duration of operation of the seven studies was significantly different between those who developed postoperative SSI and the control group [$SMD=0.78$, (95% CI; 0.22, 1.34), $P=0.006$]. Longer duration of operation was related to a greater threat of developing SSI among patients who underwent foot and ankle surgery [$SMD=1.45$, (95% CI; 0.81, 2.09)], while longer operation duration was associated with a lower risk of SSI among those who underwent pilonidal operations [$SMD=-0.13$, (95% CI; 0.73, 0.48)] (Figure 3).

Heterogeneity and publication bias

Publication bias was estimated by visual check of the funnel plot (figure 4). Visual inspection shows symmetrical distribution of the standardized mean differences obtained from the studies. Significant inter-study heterogeneity was detected among the studies that indicated the SSI prevalence and the effect of operation duration on SSI incidence ($I^2 = 93\%$).

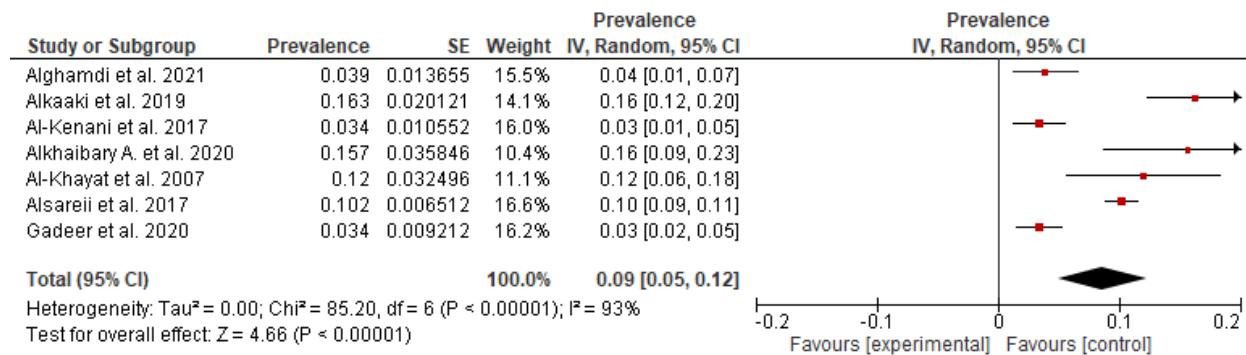


Figure 2 Forest Plot of the prevalence of SSI in post-operative patients.

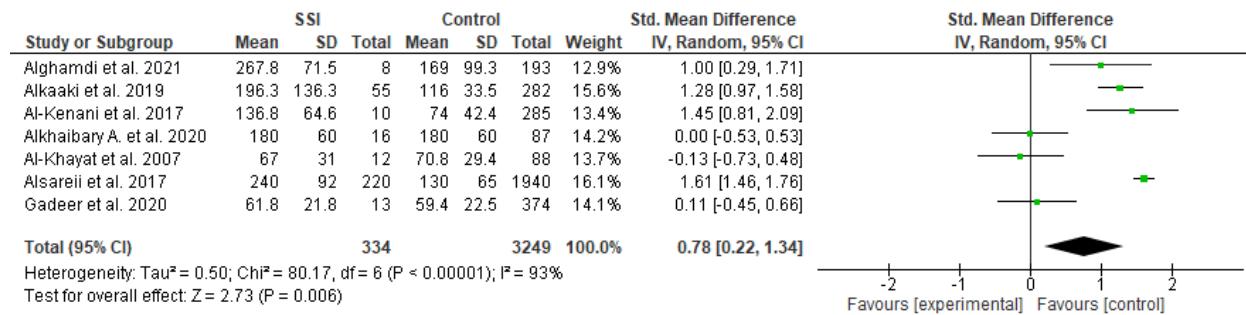


Figure 3 Forest plot showing the pooled effect of operation duration on SSI.

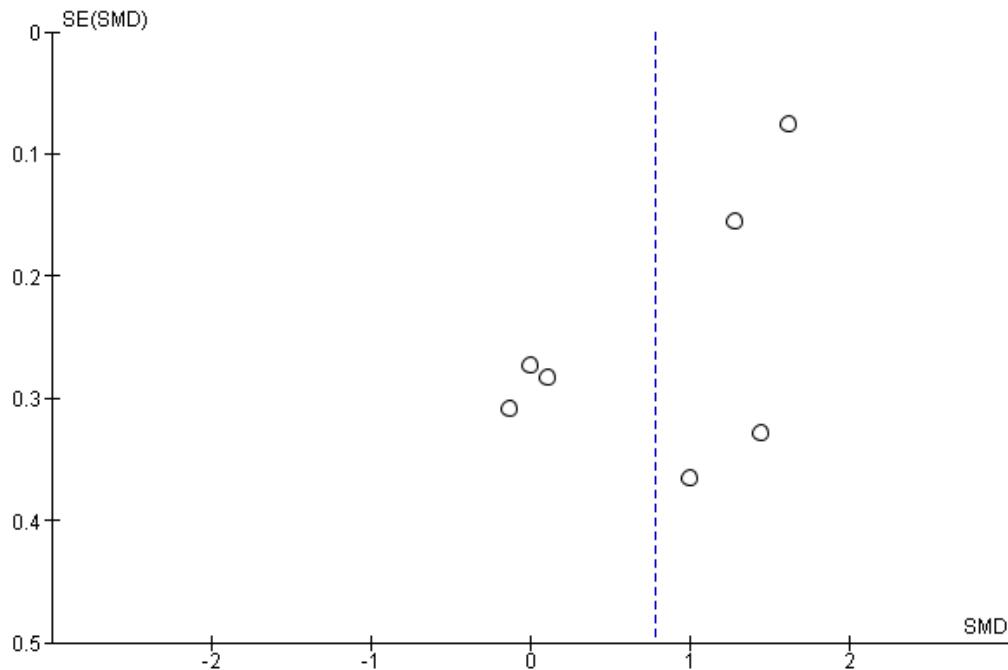


Figure 4 Funnel plot to test publication bias of the 24 studies.

4. DISCUSSION

Today, SSIs are the most popular type of healthcare-associated infection (HCAI) and have the highest global cost on the healthcare system (Allegranzi *et al.*, 2011). This systematic review and meta-analysis were conducted to estimate the prevalence of post-operative SSI in Saudi Arabia and the effect of duration of operation on the incidence of SSI. In the current study, the pooled SSI prevalence in Saudi Arabia was 9%. This finding suggests that SSIs are common in hospital patients and represent inadequate infection prevention implementation in Saudi Arabia. The overall pooled prevalence in this study was lower than the SSI prevalence estimated in Ethiopia (12.3%) (Shiferaw *et al.*, 2020) and the average prevalence in the developing countries (11.8%) (Allegranzi *et al.*, 2011). However, it was higher than the global prevalence (3.8%) (Korol *et al.*, 2013), the prevalence in China (4.5%) (Fan *et al.*, 2014), and the Eastern Mediterranean (7.9%) (Maleknejad *et al.*, 2019).

Hospitals must conduct at least one annual survey of the incidence of healthcare-related pollutions and employ a minimum one specialized for every 200–250 beds. Simultaneously, they must implement hospital-wide surveillance as well as antimicrobial drug surveillance affecting patients and medical staff. Since 2005, 147 developing countries have committed to reducing healthcare-associated infections by signing the WHO's First Global Patient Safety Challenge declaration, along with 46 developed countries (Pittet and Donaldson, 2005).

The highest prevalence was found among patients with autologous cranioplasty (16%) while women who underwent cesarean section recorded the lowest prevalence (3%) in this study. Patients suffering from traumatic brain injuries may have skull fractures or scalp lacerations, which can increase the risk of infection. Larger bone defects may be accompanying a greater threat of infection as a result of skin tension and longer operation times, which can result in wound dehiscence (Riordan *et al.*, 2016). A study has looked back at the risk influences for implant infection after cranioplasty. Long operation times (more than 120 minutes), craniectomy with temporalis muscle excision, the presence of sub-galeal collection preoperatively, and postoperative wound disturbance were all identified as predictors of infection (Kim *et al.*, 2013).

Prolonged duration of operation was considerably concomitant with a greater risk of post-operative SSI incidence in this study [SMD=0.78, (95% CI; 0.22, 1.34), P=0.006]. Another systematic review and meta-analysis reported that was a possible risk factor for SSI incidence [OR=1.78, (95% CI; 1.06, 2.94)], which was consistent with our results (Shiferaw *et al.*, 2020). Longer surgery duration increases the risk of surgical wound contamination owing to enhanced microbial exposure in the procedure field, as well as the extent of tissue trauma due to an extensive surgical procedure and increased blood loss, which contributes to tissue hypoxia (Thanni *et al.*, 2004). The infection rate nearly doubles with each hour of surgery, according to the estimated length of the surgical procedure. Furthermore, guidelines advised restraining the time of the operation; the elongated the incision leftovers open, the greater the risk of microorganisms entering the surgical incision (Curless *et al.*, 2018).

The highest risk of SSI was found in the prolonged duration of foot and ankle surgery, while lower SSI risk was associated with prolonged pilonidal operations in this study. The incidence rate of SSI after elective foot and ankle surgery was approximately 5 to 10 times higher than the elective knee and hip arthroplasty (Wukich *et al.*, 2010). According to a review of 1737 cases, this is due to the abundance of eccrine sweat glands and the hot and humid environment, which causes microbiological flora in the feet. Furthermore, the structural connection of the toes is a significant contributor, which may reduce the efficacy of preoperative skin disinfection (Ralte *et al.*, 2015). Tachibana discovered that the fore foot had a higher density of microorganisms than the rest of the foot. It had also been demonstrated that removing bacteria as of the forefoot before operation was extra difficult (Tachibana, 1976).

Limitations

There are limitations to the current meta-analysis that would be reflected in upcoming investigations. It may have required nationwide demonstration as no figures from all regions of Saudi Arabia were found. Additionally, this study pooled only the effect of one possible risk factor, the influence of length of procedure on postoperative SSI. As a result, more research is needed to identify causes and influences of the development of SSI in postoperative patients. Individual information was not available in some studies. Another limitation is the lack of data in the included studies on the type of SSIs (superficial incisional, deep incisional, or organ/space). If they could be identified, we would have a better understanding of the epidemiology of SSIs. Furthermore, a significant factor, an aspect that was not properly managed, is the determination of related risk factors, which was not taken into account in this study. The type of some surgical procedures can influence the rate of SSI, but their sub-group could not be studied.

5. CONCLUSION

This systematic review and meta-analysis have reported a relatively high prevalence of SSI (9%) in Saudi Arabia. The least SSI prevalence rate was found among women who underwent cesarean section while the highest prevalence rate was associated with autologous cranioplasty. We found that prolonged duration of operation was meaningfully linked with a greater incidence of postoperative SSI. The highest risk of SSI was found in prolonged duration of foot and ankle operations; however, lower risk SSI was associated with prolonged pilonidal operations in this study.

Author Contributions

All the authors contributed evenly in setting the study design, research objectives, data collection plan, data presentation, reviewing the results and the manuscript writing.

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Conflict of Interest

The authors declared that there are no conflicts of interest.

Data and materials availability

All data associated with this study are present in the paper.

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